ANNUAL NASA PROGRESS REPORT

COOPERATIVE AGREEMENT No. NCCW-0062

"Keck Observatory Collaboration"

9/30/1994 - 8/31/2000

During the second year of the collaboration, important progress was accomplished.

A. Technical status

Keck I observatory operations have continued to improve and the past four months were without major incident. Time lost to Hardware & Software problems continue to decrease substantially and overall efficiency is being monitored to determine where further improvements can be made. Optical performance is continuing to improve and the current performance on engineering tests proceeds to be close to the observatory design goals. A significant software bug was uncovered and corrected in the optical alignment procedures that are used to improve image quality on the scientific instruments. Software development continues at a high level and several other important improvements have been made.

Keck II construction progress continues toward completion with current plans to start operations in October 1996. Telescope positioning hardware integration is progressing with installation and initial alignment of the adjustable bar code, PRM reader mounts, azimuth and elevation encoders, and the first bent Cassegrain rotator, in preparation for PCS integration. Azimuth and elevation servo position loops have been closed. Adjustments to the forward Cassegrain module defining points and transport rail system for module interchangeability between telescopes are progressing. The primary mirror subcells have been surveyed and adjusted. The f/15 secondary module, including an aluminized mirror, mercury girdle and the vacuum system, has been installed on the telescope and the module has been recentered to put the optical center of the mirror within 0.2 mm of the telescope optic center. The tertiary tower defining points were adjusted to correct for a decenter of 6.5 mm and a tilt of 7 arcmin. The tertiary mirror truss and subcell have been installed in the tertiary module and the tertiary mirror has had its whiffletrees installed and has been aluminized. The star stacking camera has been assembled and aligned and its bent Cassegrain rotator has been installed on the telescope. Twelve primary mirror segments are on the summit in preparation for installation. Six of the segments have been aluminized. The Active Control System cabling to the node boxes, and the node boxes themselves, have been installed on the telescope and are ready for segment installation.

A seismic preparedness review of the telescopes and support facility was performed with assistance from Caltech faculty and staff. An action plan was developed for critical hardware, susceptible to seismic damage, and is being implemented.

Progress continued on the development of adaptive optic (AO) and interferometric capabilities. Seven of the eight open design issues that were identified at the May 1995 Conceptual Design Review meeting have been resolved. The results were: off-axis laser projection; two techniques compensating for sodium beacon distance variations; alignment of NIRC-2 to the AO bench; pump lasers on the dome floor; fixed AO bench; and the two LLNL subsystem contracts in place. The remaining issue, development of phased development

plans, will be addressed at the PDR. The AO software design book is continuing to progress, especially the system architecture, high level coordination sequences, and the wavefront controller interface definition. Lick Observatory and CARA staff have collaborated to produce a PDR level design of the AO bench mounting to the Nasmyth platform, JPL has been working on an alignment study, and Wynne has produced an IR atmospheric dispersion corrector design.

B. Telescope Commissioning and Usage

During the last quarter, the telescope was scheduled 92 of 92 nights. Twelve nights were scheduled for engineering, 9 with PCS, 1 with LRIS, or 13% of the available time. In addition, 6 nights were devoted to LWS commissioning. LRIS was used on 39 nights or 42%, NIRC on 18 nights or 20% and HIRES on 17 nights or 18%. Of the scheduled nights, 87% was for science observing or instrument commissioning and 13% was telescope engineering. Overall the total available time was distributed as: 9% weather lost, 42% science integration time, 18% engineering time and the balance was consumed by hardware and software problems and telescope/instrument start up time (Set up, find object, slew time, rotator time loss, etc.). The lost time from H/W & S/W problems of 7% was significantly reduced relative to the previous period, which has resulted in more science integration time. Of the 12 engineering nights, most were devoted to optical alignment and segment exchange. The median image quality was roughly 0.70 arc seconds during the period. This imaging performance is unsurpassed for any large telescope in its first few years of full operation, a tribute to the care that went into the design for maintaining good thermal conditions inside the dome. Realization that the images delivered to astronomers could be much better has focused our attention on that objective in the future.

Scientific Instruments -- High Resolution Echelle Spectrometer (HIRES) continues to be used routinely with high efficiency and reliability. Low Resolution Imaging Spectrograph (LRIS) had the most use at 42%. Near-Infrared Camera (NIRC) is used routinely for observations <2.5 μm. Long Wavelength Spectrometer (LWS) was in the process of being commissioned during this period with 6 nights devoted to that activity in the September engineering period. That initial LWS commissioning was completed, with diffraction limited images recorded at approximately 12 microns, and all LWS software integrated into the observatory environment. Compensation of focus for rotator angle has been implemented, but is currently only used for LWS. LRIS coefficients have been determined, but are not yet tested. Rotator command latency has been reduced from ~15 seconds to ~3 seconds. Further improvement will be deferred until the Keck I retrofit.

W. M. Keck Telescope Science Highlight for the period -- Astronomers reported finding the most distant galaxy ever detected. At 14 billion light years from earth, the discovery pushes back the earliest known time when galaxies were formed to only one billion years after the current estimate for the "Big Bang" birth of this universe. The discovery was announced by Caltech researcher Thomas Barlow, who said that the spectrum shadow of the galaxy was found by his team during observation of an even more distant quasar, one of the brightest bodies in the universe. Observation of a galaxy of that age, with characteristics similar to galaxies that formed much later, and its apparent rapid accumulation may impact a number of current theories on the early evolution and age of the universe.

C. Work in the coming year

Telescope operational completion is scheduled for this next period, including; final work on Dome installation, Mirror support and Control system, Optics installation, and System test, with First Light planned for early in this period. --Adaptive Optics -- PDR was set for early in the next period for all AO subsystems, excluding the laser subsystem, to provide a design configuration.

D. Papers presented at conferences and Journal Articles

ACCEPTED FOR PUBLICATION

Keck Spectroscopy and HST Imaging of Field Galaxies at Moderate Redshift: D. Forbes, A. Phillips, D. Koo, G. Illingworth: accepted for publication in Ap J

PUBLISHED ARTICLES

Near Infrared Spectra of Arp 220: Spatially Resolved CO Absorption in the Inner Kiloparsec: L. Armus, G. Neugebauer, B.Soifer, K. Matthews: AJ, 21Oct95, vol.452, p.522

The Brown Dwarf Candidate 0918-0023B is a Distant Compact Galaxy: E. Becklin, B. Macintosh, B. Zuckerman: ApJ, 20Aug95, vol. 449, p. L117

A Surprise at the Bottom of the Main Sequence: Rapid Rotation and No H Alpha Emission: G. Basri, G. Marcy: AJ, Feb95, vol. 109, p.762

Spectropolarimetry of Two Broad absorption Line Quasars with the W. M. Keck Telescope: M Cohen, P. Ogle, H. Tran, R. Vermeulen, J. Miller, R. Goodrich , A. Martel: Ap J Letters, 1Aug95, vol. 448, p.L77

Detection of Massive Forming Galaxies at Redshifts Greater than One: L.Cowie, E. Hu, A. Songaila: Nature, 19Oct95, vol.377, p.603

The Metallicity and Internal Structure of the Lyman-Alpha Forest Clouds: L. Cowie, A. Songaila, T. Kim, and E. Hu: Institute of Astronomy, University of Hawaii: AJ, Apr95, 109, p.1522.

Evidence of Higher Primordial Lithium from Keck Observations of M92: C. Deliyannis, A. Boesgaard, J. King: ApJ Letters, 10Oct95, vol.452, p.L13

Discovery of a z=2.76 Dusty Radio Galaxy?: A. Dey, H. Spinrad and M. Dickinson: Ap J , 20Feb95, 440, 515.

Deep Galaxy Counts in the K-band with the Keck Telescope: S. Djorgovski, B.T. Soifer, M.A. Pahre, J.E. Larkin, J.D. Smth, G. Neugebauer, I. Smail, K. Matthews, D.W. Hogg, R.D. Blandford, J. Cohen, W. Harrison; J. Nelson: ApJ, 1Jan95, 438, L13.

The Mass of the Probable Black Hole in the X-Ray Nova GRO J0422+32 : A. Filippenko, T. Matheson, L. Ho: ApJ , 20Dec95, vol. 455, p. 614.

A Black Hole in the X-Ray Nova GS 2000+25 : A. Filippenko, T. Matheson, A. Barth: ApJ Letters , 20Dec95, vol. 455, L139.

High-resolution Infrared Imaging of FSC 10214+4724 : Evidence for Gravitational Lensing: J. Graham and M. Liu: ApJ Letters, 10Aug95, vol.449, p.L29

The Collision of Fragment R of Comet P/Shoemaker-Levy 9 with Jupiter Observed by the W.M. Keck Observatory: Graham, de Pater, Jernigan, Liu, Brown: Dept. of Astrophysics, U.C. Berkeley: Science, 3Mar95

Probing the Interstellar Medium Along the Lines of Sight to Supernovae SN 1994D and SN 1994I: L. Ho, A. Filippenko: ApJ, 1May95, 444, p.165.

High-Resolution Spectra of Distant Compact Narrow Emission Line Galaxies: Progenitors of Spheroidal Galaxies?: D. Koo, R. Guzman, S.M. Faber, G. Illingworth, M. Bershady, R. Kron, and M. Takamiya: Ap J , 20Feb95, 440, L49.

An Emission-Line Protogalaxy Candidate at z = 2.5 : M. Malkan, H. Teplitz, I. McLean: ApJ Letters, 20Jul95, vol.448, p.L5

Stellar Abundances and Winds of A-type Supergiant Stars in M33: First Results from the Keck HIRES Spectrograph: J. McCarthy, D. Lennon, K. Venn, R. Kudritzki, J. Puls, F. Najarro: ApJ Letters, 20Dec95, vol. 455, L135.

1608+656: A Quadruple-lens System Found in the CLASS Gravitational Lens Survey : S. Myers, C. Fassnacht, S. Djorgovski, R. Blandford and others: ApJ Letters, 1Jul95, 447, p.L5

The Keck Low-Resolution Imaging Spectrometer: J.Oke, J. Cohen, M. Carr, J. Cromer, A. Dingizian, F. Harris, S. Labrecque, R. Lucinio, W. Schaal, H. Epps, J. Miller: PASP, Apr 95, p.375

A Near-Infrared Search for Line Emission from Protogalaxies Using the W.M. Keck Telescope: M. Pahre, S. Djorgovski: ApJ Letters,10Aug95, vol.449, p.L1

The Discovery of two Giant Arcs in the Rich Cluster A2219 with the Keck Telescope: I. Smail, D. Hogg, R. Blandford, J. Cohen, A. Edge, S. Djorgovski: MNRAS, 1Nov95, vol.277, p.1

Deep Optical Galaxy Counts with the Keck Telescope: I. Smail, D. Hogg, L. Yan, J. Cohen:ApJ Letters, 20Aug95, vol. 449, p.L105

Near Infrared Observations of IRAS~09104+4109: B. Soifer, G. Neugebauer, L. Armus, D. Shupe: AJ

Near Infrared and Optical Spectroscopy of FSC10214+4724: B.T. Soifer, J.G. Cohen, L. Armus, K. Matthews, G. Neugebauer and J. B. Oke: ApJ, 20Apr95, 443, L65

A Population of Very Diffuse Lyman-alpha Clouds as the Origin of the He+ Absorption Signal in the Intergalactic Medium: A Songaila, E. Hu, L. Cowie: Nature, 11May95, vol.375, p.124

Keck Observations of the Most Distant Galaxy: 8C 1435+63 at z=4.25: H. Spinrad, A. Dey and J. Graham: ApJ, 10Jan95, 438, L51.

The Nature of the Stellar continuum in the Radio Galaxy 3C 65: A. Stockton, M. Kellogg, S. Ridgway: Institute for Astronomy, University of Hawaii : Ap J, 20Apr95, 443, L69.

Spectroscopy of the White-Dwarf Companions of PSR 0655+64 and 0820+02: M. van Kerkwijk, S. Kulkarni: ApJ Letters, vol. 454, p. L141

Internal Kinematics of the Leo II Dwarf Spheroidal Galaxy: S. Vogt, M. Mateo, E.W. Olszewski and M.J. Keane: AJ, 1995, 109, 151.

Search for Coronal Emission Lines in Cooling Flow Clusters with the Keck 10-meter Telescope: L. Yan, J. Cohen: Ap J, 20Nov95, vol.454, p.44

CONFERENCE PROCEEDINGS

Lithium in Pleiades K Dwarfs: D. Soderblom, B. Jones, M. Shetrone: Light Element Abundances, Proceedings of an ESO/EIPC Workshop; Isola d'Elba, Italy, 22-28 May 1994: published by Springer 1995

The Galactic Evolution of Beryllium: A. Boesgaard: Light Element Abundances, Proceedings of an ESO/EIPC Workshop; Isola d'Elba, Italy, 22-28 May 1994: published by Springer 1995

First Keck Results for DEEP (Deep Extragalactic Evolutionary Probe): David Koo: 35th Herstmonceaux Conference: Wide Field Spectroscopy and the Distant Universe.

Faint Field Galaxy Counts, Colors, and Redshifts: David C. Koo: Examining the Big Bang and Diffuse Background Radiations, Proceedings of IAU No. 168, ed. M. Kafatos.